

LONG TERM DURABILITY PROPERTIES OF HIGH STRENGTH SELF COMPACTING CONCRETE USING MINERAL ADMIXTURES

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ABSTRACT

In this paper it was attempted to study the long term durability properties for High Strength Self Compacting Concrete specimens immersed in acids and sulphate solutions. The losses of weight as well as loss of Compressive strength and the durability factors are also evaluated. It was found that specimens exhibit some changes when subjected to acids however no change is observed when immersed in sulphate solutions.

KEYWORDS: Self Compacting Concrete, Acid Attack, Sulphate Attack, Durability Factors

INTRODUCTION

For reduction of column sizes, to increase the available space and to built super structures of longer span high strength self compacting concrete is needed. For longer serviceability as well as maintenance of the structure studies on durability aspect is very much needed. When the specimen are subjected to attack with acids all the cement compounds are leached away by breaking in to pieces together with any carbonate aggregate material. When specimens are subjected to the sulphuric acid calcium sulphotoaluminate will be formed. The calcium sulphotoaluminate on crystallization causes expansion and disruption of concrete. If acids or salt solutions are able to reach the reinforcing steel through cracks or porosity of concrete, corrosion can occur which will cause cracking. When specimens are subjects to sulphates a product called Ettringite will be generated. This new compound causes expansion and disruption of the concrete. So it is essential to limit the permeability of the concrete to reduce the penetration of sulphates in solution. An increase in the volume of cement paste in concrete or mortar due to the chemical action between the products of hydration of cement and solution containing sulphates is observed. The deteriorating effect usually starts at the surface and corners and progressively enters into the concrete by causing scaling and spalling and finally reduces the concrete a friable mass.

LITERATURE REVIEW

With increasing c/p ratio and consequently increasing cement content and decreasing w/c ratio, a decrease of the creep deformations is found. The fineness of the tested fillers has almost no influence on the deformations⁽¹⁾. The author in his paper the effect of Glass fibres in improving the durability aspects⁽²⁾. In their investigation they concluded that the steel fibres have improved the durability aspects of Self Compacting concrete specimens.⁽³⁾ The extensive investigations made in the development of self-compacting concrete with reduced segregation potential has concluded that the fine particle content is increased by replacing partially the fine and coarse aggregates by low-calcium fly ash⁽⁴⁾.

Investigations made on the effect of glass fibres on durability properties have shown that The glass fibres are having the impact on the on the durability properties of glass fibre self compacting concrete for different grades of concretes M 30 to M65 and also on the about durability factors⁽⁵⁾. The effective usages of Mineral admixtures have yielded the High strength Self Compacting Concrete Mix 100⁽⁶⁾. In the investigation on the effect of Micro silica and superplasticizer on the durability of concrete to phosphoric acid, the result showed the combined effect of usage of Micro silica was the best to enhance the durability of concrete to phosphoric acid without major effect on response of concrete⁽⁷⁾. The author in his paper explained that mineral admixtures contribute effectively a lot not only for achieving durability but also high strength⁽⁸⁾.

RESEARCH SIGNIFICANCE

The available literates indicate about studies of self compacting as well as fibre reinforced self compacting concrete mixes. As the need of high strength and high performance concretes for today's need, it has become essential to study the durability properties of High Strength self compacting concrete. Considering the need an effort was made to study the long term durability parameters of i.e. Loss of weight and loss in compressive strength of specimens due to acid attack, sulphate attack and also effect of Acids and Sulphates on durability properties.

MATERIALS

Cement

Ordinary Portland cement of 53 grade having specific gravity of 3.02 and fineness of 3200cm²/gm was used in the investigation. The Cement used has been tested for various proportions as per IS 4031-1988 and found to be confirming to various specifications of are 12269-1987.

Coarse Aggregate

Crushed angular granite metal of 10 mm size having the specific gravity of 2.65 and fineness modulus 6.05 was used.

Fine Aggregate

River sand having the specific gravity of 2.55 and fineness modulus 2.77 was used.

Viscosity Modifying Agent

A Viscosity modified admixture for Rheodynamic Concrete which is colourless free flowing liquid and having Specific of gravity 1.01±0.01 @ 25°C and pH value as 8±1 and Chloride Content nil was used.

Admixture

The Modified Polycarboxylated Ether based superplasticizer which is pale yellow colour and free flowing liquid and having Relative density 1.10±0.01 at 25°C, pH >6 and Chloride Ion content <0.2% was used.

Fly Ash

Type-II fly ash confirming to I.S. 3812 – 1981 of Indian Standard Specification was used.

Micro Silica

The Micro silica having the specific gravity 2.2 was used in the present investigation

TEST PROCEEDURE

The test specimens of size 100 X100 X 100 mm cubes are immersed 10% sodium sulphate, 10% H_2SO_4 solution and 10% HCL solution respectively. The deterioration of specimens is presented in the form of percentage reduction in weight and percentage reduction in compressive strength concrete of specimens at 28, 56, 90, 180, 270 and 360 days.

DISCUSSIONS OF RESULTS

Quantities of Materials and Fresh State Properties of High Strength Self Compacting Concrete Mixes

The Table 1 gives the various trail mixes have been carried out by varying % of Fly ash and % of Micro silica to get M100 grade High Strength Self compacting Concrete Mix. At 15% of Micro Silica and 25% of Fly ash we observed M100 Strength. Table 2 provides the fresh state properties of Mix 10 whose compressive strength for 7 days and 28 days have been noted. As it is evident, the basic requirements of high flow ability and segregation resistance as specified by guidelines by EFNARC are satisfied.

Percentage Loss of Weight and Loss of Compressive Strength and Durability Factors of Specimens Immersed in Acid and Sulphate Solutions

Table 3 gives the average percentage loss of weight of the specimens immersed in 10 % HCL, 10% Na_2SO_4 and 10% H_2SO_4 solution. It is observed the percentage loss of weight is to vary from 1.68 % for 28 days to 9.62 % for 360 days in HCL solution, the effect is nil for all the ages in Na_2SO_4 solution and to vary from 8.12 % for 28 days to 35.63 % for 360 days in H_2SO_4 solution.

Percentage Loss of Compressive Strength and Durability Factors of Specimens Immersed in Acid and Sulphate Solutions

Table 4 gives the average percentage loss of compressive strength of the specimens immersed in 10 % HCL, 10% Na_2SO_4 and 10 % H_2SO_4 solution. It is observed the percentage loss of Compressive Strength is to vary from 4.74 % for 28 days to 22.23 % for 360 days in HCL solution, the effect is nil for all the ages in Na_2SO_4 solution and to vary from 22.21 % for 28 days to 61.08% for 360 days in H_2SO_4 solution.

Durability Factors of Specimens Immersed in Acid and Sulphate Solutions

Table 5 gives the durability factors of the specimens immersed in 10 % HCL, 10% Na_2SO_4 and 10 % H_2SO_4 solution. It is observed the durability factors are to vary from 7.41% for 28 days to 77.77 % for 360 days in HCL solution, to vary 7.77 % for 28 days to 100.00 % for 360 days in Na_2SO_4 solution and to vary from 6.06 % for 28 days to 38.92 for 360 days in H_2SO_4 solution. From the results it is observed that the Percentage loss is increasing with age which are in line with findings of Ganeshan (3) and Seshadri (5). The mineral admixtures enhanced the durability effects against Sulphates which is in line with findings of seshadri(7) and Shekar Reddy (8).

The specimens when immersed in HCL solution, as the attack proceeds, all the cement compounds are evenly broken down and leached away, together with carbonate aggregate material. That is the reason the percentage in weight as well as compressive strength loss is increasing with time. Form durability factors we observe that the specimens are vulnerable in HCL solution. The specimens when immersed in H_2SO_4 solution, with the sulphuric acid attack, calcium sulphate formed can be proceed to react with calcium alumininate to form calcium sulphotoaluminate which causes disruption of concrete by way of expansion. The percentage Loss of weight as well as Compressive strength is more.

From durability factors we can observe that the specimens are more vulnerable. The specimens when immersed in Na_2SO_4 solution, incorporation of pozzalona material reduces the sulphate attack. The pozzolona which is responsible for conversion of leachable calcium hydroxide to non leachable cementitious product is responsible for impermeability of concrete. By such we observe that Na_2SO_4 solution indirectly helping in curing the specimens.

CONCLUSIONS

- High Strength Self Compacting Concrete mix M 100 is developed with the addition of 15% Micro silica and 25% Fly ash with Water to Powder ratio of 0.22.
- The percentage Loss of weight and Loss of Compressive strength of concrete specimens after immersing in HCL solution varied from 1.68% to 9.62 % and 4.74% to 22.63%.
- The percentage Loss of weight and Loss of Compressive strength of concrete specimens after immersing in H_2SO_4 solution varied from 8.12% to 35.63%.and 22.21 to 61.08%.
- The percentage Loss of weight and Loss of Compressive strength of concrete specimens after immersing in Na_2SO_4 solution is Nil.
- Higher the resistance to acids higher will be the Durability factor.

REFERENCES

1. Anne-Mieke et.al “Creep and Shrinkage Of Self Compacting Concrete”, International conference on Advances in Concrete, Composites and Structures, held at SERC, Chennai, 6-8 January, 2005 PP 329-336.
2. Dr Srinivasa Rao et.al “Study on Strength and Durability Characteristics of Glass Fibre Concrete”, in International Journal of Mechanics and Solids Vol 5, No 1 (2010) PP 15-26.ISSN -0973-1881
3. Ganesan.N et.al “Durability aspects of steel fibre- reinforced SCC”, The Indian Concrete Journal, May 2006, PP 31-37.
4. Dr. R. Sri Ravindrarajah, et.al “Development of high strength self compacting concrete with reduced segregation potential” Proceedings of the 3rd International RILEM Symposium, Reykjavik, Iceland, 17-20 August 2003, Edited by O. Wallevik and I. Nielsson, (RILEM Publications), 1 Vol., 1048 pp., ISBN: 2-912143-42-X, soft cover.
5. T. Seshadri Sekhar et.al “Durability Studies on Glass Fibre Compacted Concrete”, Indian concrete Journal Vol 83 No 10, October 2009, No 10, PP 44-52
6. T. Seshadri Sekhar et.al “High Strength Self Compacting concrete using mineral admixtures”, Indian concrete Journal March 2013 Vol 87 No 3 PP 42-48.
7. T. Seshadri Sekhar et.al “Effect of mineral admixtures on the behavior of high strength self compacting concrete under acid and sulphate attacks” in Global Journal of Engineering and Applied Sciences (GJEAS)” Volume 3. No 1. (January – March (2013) PP 4 to 7. ISSN 2249-2625
8. Sekhar Reddy et.al Strength and Durability-Related Properties of High Performance Concrete with Mineral and Chemical Admixtures the IUP Journal of Structural Engineering, Vol. VI, No. 3, July 2013, pp. 39-52

APPENDICES

Table 1: Quantities of Materials for 1m³ for Various Trail Mixes of High Strength Self Compacting Concrete

Mix	Cement (kg/m ³)	Fly Ash (kg/m ³)	Micro Silica (kg/m ³)	Water (kg/m ³)	Coarse Aggregate (kg/m ³)	Fine Aggregate (Kg/m ³)	SP (kg/m ³)	V.M.A (Kg/m ³)
Mix 1	500	150	50	154	769.852	740.801	10.5	0.56
Mix 2	500	125	75	154	769.517	740.479	10.5	0.56
Mix 3	500	100	100	154	769.182	740.156	10.5	0.56
Mix 4	500	125	75	154	769.517	740.479	10.5	0.56
Mix 5	500	125	75	154	769.633	740.590	10.5	0.56
Mix 6	500	125	75	140	788.067	758.329	10.5	0.56
Mix 7	500	100	100	140	787.732	758.007	10.5	0.56
Mix 8	500	125	75	140	788.067	758.329	10.5	0.56
Mix 9	500	125	75	140	790.405	781.440	13.3	0.35
Mix 10	500	125	75	154	774.985	766.195	11.2	0.35

Table 2: Fresh Concrete Properties of High Strength Self Compacting Concrete Mix 10

Tests Conducted	Mix 10	Permissible Limits as Per EFNARC Guidelines		Compressive Strength (N/mm ²)	
		Min	Max	7 Days	28 Days
V-Funnel	12 sec	6 sec	12 sec	93.62	117.03
Abrams Slump Flow	665 mm	650mm	800mm		
T _{50cm} Slump Flow	4.5 sec	2 sec	5 sec		
L-Box	H ₂ /H ₁	0.82	1.0		
	T ₂₀	1sec	2 sec		
	T ₄₀	2sec	3sec		
V-Funnel at T _{5 Min}	14 sec	11 sec	15 sec		

Table 3: Percentage Loss of Weight of High Strength Self Compacting Mixes

Grade of Concrete	10% HCl Solution						10% Na ₂ SO ₄ Solution						10% H ₂ SO ₄ Solution					
	28 Days	56 Days	90 Days	180 Days	270 Days	360 Days	28 Days	56 Days	90 Days	180 Days	270 Days	360 Days	28 Days	56 Days	90 Days	180 Days	270 Days	360 Days
M 100	1.68	3.74	4.25	5.92	7.58	9.62	0	0	0	0	0	0	8.12	14.78	23.38	27.98	31.95	35.63

Table 4: Percentage Loss of Compressive Strength of High Strength Self Compacting Mixes

Grade of Concrete	10% HCl Solution						10% Na ₂ SO ₄ Solution						10% H ₂ SO ₄ Solution					
	28 Days	56 Days	90 Days	180 Days	270 Days	360 Days	28 Days	56 Days	90 Days	180 Days	270 Days	360 Days	28 Days	56 Days	90 Days	180 Days	270 Days	360 Days
M 100	4.74	6.28	9.38	12.78	15.98	22.23	0	0	0	0	0	0	22.21	29.42	38.40	48.45	57.36	61.08

Table 5: Durability Factors of High Strength Self Compacting Mixes at Different Ages When Immersed in Different Solutions

Grade of Concrete		10% HCl Solution		10% Na ₂ SO ₄ Solution		10% H ₂ SO ₄ Solution	
		Sr	D.F	Sr	D.F	Sr	D.F
M 100	28	95.26	7.41	100.00	7.77	77.79	6.06
	56	93.72	14.58	100.00	15.55	70.60	10.98
	90	90.62	22.66	100.00	25.00	61.60	15.40
	180	87.22	43.61	100.00	50.00	51.55	25.78
	270	84.02	63.02	100.00	75.00	46.24	34.68
	360	77.77	77.77	100.00	100.00	38.92	38.92



Figure 1: Test Specimens of High Strength SCC Mix of M100 Grade Immersed in HCL, Na_2SO_4 and H_2SO_4 Solution

AUTHOR'S DETAILS



Dr P. Srinivasa Rao, Professor, Specialized in structural engineering. Research interests are Concrete Technology, Structural Design, High Performance Concrete, Prefabricating Structures, Special Concretes and use of Micro Silica, Fly Ash in Building Materials. He has been associated with a number of Design projects, for number of organizations and involved as a key person in Quality control and Mix Designs. Has 28 years of academic, research and industrial experience published over 100 research papers. He guided 5 Ph.Ds and 100 M.Tech projects. Guiding 15 Ph.D students delivered invited lecturers in other organizations and institutions. Member of ISTE, Member of ICI and Member of Institute of Engineers.



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